The effects of awkward versus natural shoulder configurations on elbow maximal torque based on isokinetic dynamometer

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Introduction

In industrialized countries, musculoskeletal disorders (MSD) represent 80% to 90% of work related disorders. Ulnar nerve entrapment (UNE) and epicondylitis are the most common elbow MSDs within manual workers (1,2). UNE and epicondylitis are associated with maintained elbow flexion, or near-maximal elbow extension coupled with large loads (3). Awkward shoulder postures while using elbow increase MSD risk (4). Articular mechanical load can be estimated in regards of its maximal isometric torque from dynamometric measurements (5). Most studies focusing on elbow ergonomics considered tasks executed in one – usually natural – shoulder configuration. A comparison between elbow isometric torque characteristics in natural and awkward shoulder configurations could help reduce the risk of elbow MSDs.

Research Question

The study highlights differences in elbow isometric torque characteristics when varying shoulder configurations and implications for ergonomics.

Methods

Dynamometric measurements and personalized torque-angle modelling were performed on a worker population to define elbow isometric torque characteristics during natural or awkward manual tasks.

Twenty-five middle-aged workers (33±6 years, 1.80±.07 m, 79±8 kg) participated in our study. One classical and five awkward shoulder configurations were tested: flexion 0° with external rotation (F0ER), 90° flexion with external rotation (F90ER), 180° flexion with external rotation (F180ER), 90° abduction with external rotation (A90ER), 90° abduction with internal rotation (A90IR), and 90° flexion with internal rotation (F90IR) (Fig. 1).

Dynamometric measurements consisted in static calibration, submaximal concentric and eccentric warm-up, and isometric trials. Trials included 5 isometric contractions maintained for 5 s in flexion and extension evenly distributed through the angular range of movement of the participants.

A quadratic torque-angle model (6) was used to fit isometric torque measurements, where model parameters: peak isometric torque Γ_{max}, maximal range of motion Γ_{max}, and optimal angle Γ_{max}, were optimized. Optimal isometric torque for awkward shoulder configurations were

compared to natural configuration in terms of: optimal model parameters (one-way repeated measures Anova), torque magnitude M and angle phase P (7).

Figure 1. Natural and awkward shoulder configurations tested for elbow torque on dynamometer.

Results

Significant effects of shoulder configuration on elbow peak isometric torque Γ_{max} are shown (p<.01). In flexion, F0ER displays larger Γ_{max} than F90ER and F180ER. In extension, F90ER shares highest Γ_{max} with F0ER larger than F180ER (table 1). Magnitude analysis also reveals that maximal isometric torque over the full range of motion is overall the largest for A90IR in flexion or F0ER in extension.

No significant differences are found for maximal range of motion RoM.

Effect of shoulder configuration on elbow optimal angle θ_{opt} is found (p<.01). F0ER, F90ER and F180ER display smallest optimal angles (closest to anatomical reference) in flexion. Inversely, F0ER and A90IR show largest θ_{opt} in extension. Phase analysis show similar correspondences.

Table 1. Awkward versus natural shoulder configuration in terms of average isometric torque parameters, torque magnitude and angle phase.

Torque direction	Shoulder configuration	Γ_{max} [N. m]	RoM [°]	θ_{opt} [°]	M [%]	P [%]
FLEXION	F0ER (natural)	60.95 ± 8.97	157 ± 10	74 ± 11	0	0
	F90ER	-9.96	+80	-2	-4	6
	F180ER	-8.88	+34	+1	-6	5
	A90ER	-5.74	+33	+21	-3	10
	A90IR	-1.21	+51	+13	+9	8
	F90IR	-1.11	+31	+20	+4	10
EXTENSION	F0ER (natural)	56.09 ± 13.34	194±70	59 ± 21	0	0
	F90ER	+3.24	+18	-29	-4	6
	F180ER	-10.2	+7	-9	-21	3
	A90ER	-9.51	-19	-3	-18	2
	A90IR	-2.77	-24	+30	-3	12
	F90IR	-3.91	7	-6	-11	4

Discussion

Peak isometric torque and magnitude results give a clear idea of elbow torque available for all shoulder configurations. Results confirm that natural position (F0ER) allows good compromise

between peak torque and torque magnitude. For flexion, F90ER and F180ER appear as weakest configurations. Except for F90ER in elbow extension tasks, shoulder flexion should be minimized in strenuous working tasks. Those results agree with common ergonomic recommendations in terms of posture (8,9).

In flexion, F0ER with smaller optimal angle could also help reduce UNE occurrence by favoring tasks with less flexed elbow. Similarly in extension, F0ER and A90IR could help reduce epicondylitis by favoring less extended elbow work.

While A90IR appears as good alternate on torque and angle criterion, visibility issue might interfere.

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